# Mechanical behavior of alkali-cements as function of the temperature

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## CONCLUSIONS

- Alkali cements are more resistant to elevated temperatures than traditional Portland cement, having a great potential for fire resistance applications. The relative residual strengths, for all alkali pastes, were superior than traditional Portland cement even after exposure up 1000 °C.
- Paste composition has a great influence on both the initial strength and the residual strength after heating.
- The optimum composition that gave the highest compressive strength was found to be 85% FA and 15% Bauxita (FBxWN).

## Objective

This investigation reports on a comparative study of the mechanical behavior at different temperatures of three different alkali-activated fly ash pastes chemically activated using sodium silicate. A control Portland cement (OPC) was used as a reference. In an attempt to **simulate the conditions prevailing in the event of accidental fire** post-thermal mechanical tests were performed to determine the residual strength. It has therefore been established that FA based cements can be fabricated for construction purposes and these materials have great potential for fire resistance applications.

## Materials

*Table 1. Chemical composition and paste mix proportions of the cementitious materials.*

| Mix | Solid | Liquid | L/S | Curing Conditions(2) | $SiO_2/Al_2O_3$ wt% ratio | $Na_2O/Al_2O_3$ wt% ratio |
|---|---|---|---|---|---|---|
| **FAWN** | 100 % FA | WN(1) | 0.35 | 20 h 85ºC 98 %RH | 1.91 | 0.26 |
| **FBWN** | 70 % FA 30 % Clay-Des | WN(1) | 0.50 | 20 h 85ºC 98 % RH | 1.91 | 0.36 |
| **FBxWN** | 85% FA 15 % Bauxite | WN(1) | 0.35 | 20 h 85ºC 98 % RH | 1.45 | 0.23 |
| **OPC** | CEM 42,5 R | Water | 0.30 | 20 h 22ºC 98 % RH | -- | -- |

(1) WN: 15 % Sodium silicate + 85 % NaOH 10M (21.03 $\%Na_2O$, 4.05 $\%SiO_2$, 74.92 $\%H_2O$)
(2) RH: Relative humidity

## Methods

### Post-thermal mechanical tests

Evaluation of residual strength after sudden, fairly brief exposure to high temperatures.

- 10 mm x 10 mm x 60 mm specimens subjected to intense heat for 1 h and abruptly cooled to room temperature.

### High-temperature mechanical tests

Study of flexural strength ($\sigma_F$) in a TPB configuration, fracture toughness ($K_{IC}$) and compressive strength ($\sigma_C$) as function of temperature (25ºC - 1000ºC).

- Test $\sigma_F$ and $K_{IC}$: 8 mm x 4 mm x 50 mm
- Test $\sigma_C$: 5 mm x 5 mm x 10 mm

*Figure 1. Photograph of FAWN samples at room temperature and after test at high temperature (Compression test at 1000ºC).* All specimens tested exhibited slightly volume instability after exposure to elevated temperatures, where their dimensions slightly increased.

## Results

### - Post-thermal mechanical tests

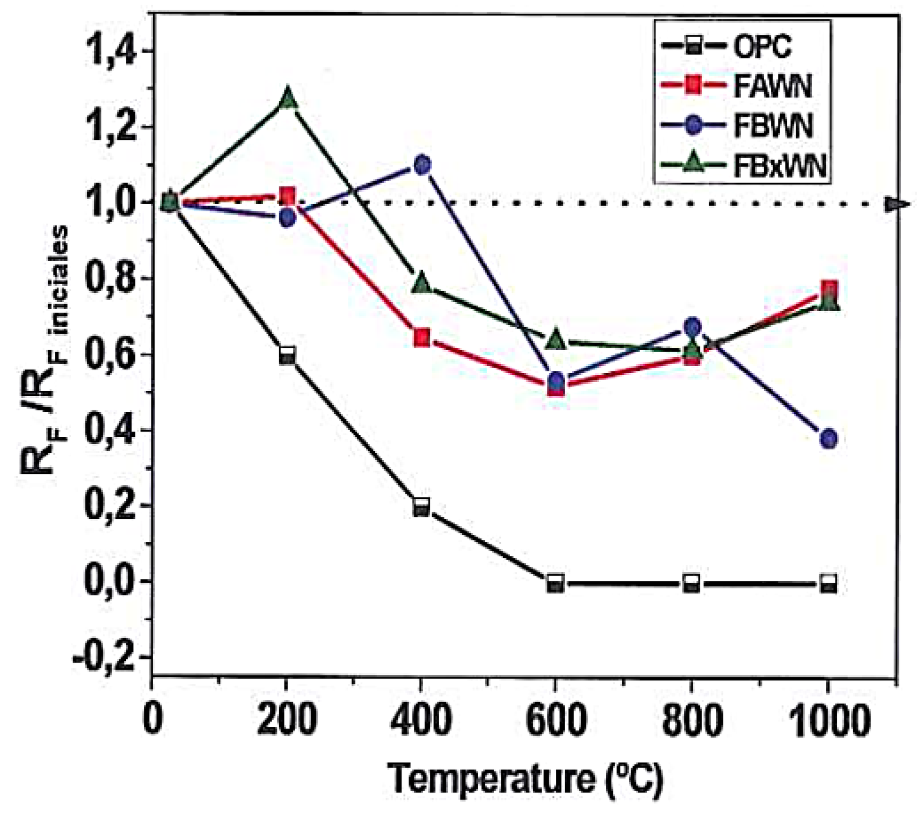


*Figure 2. Relative residual flexural strength ($\sigma_{FR}=\sigma_R/\sigma_{FO}$) versus temperature.* After thermal shock, both relative residual flexural strength and compression strength of WN pastes were significantly higher than those of OPC pastes for all the temperature range.

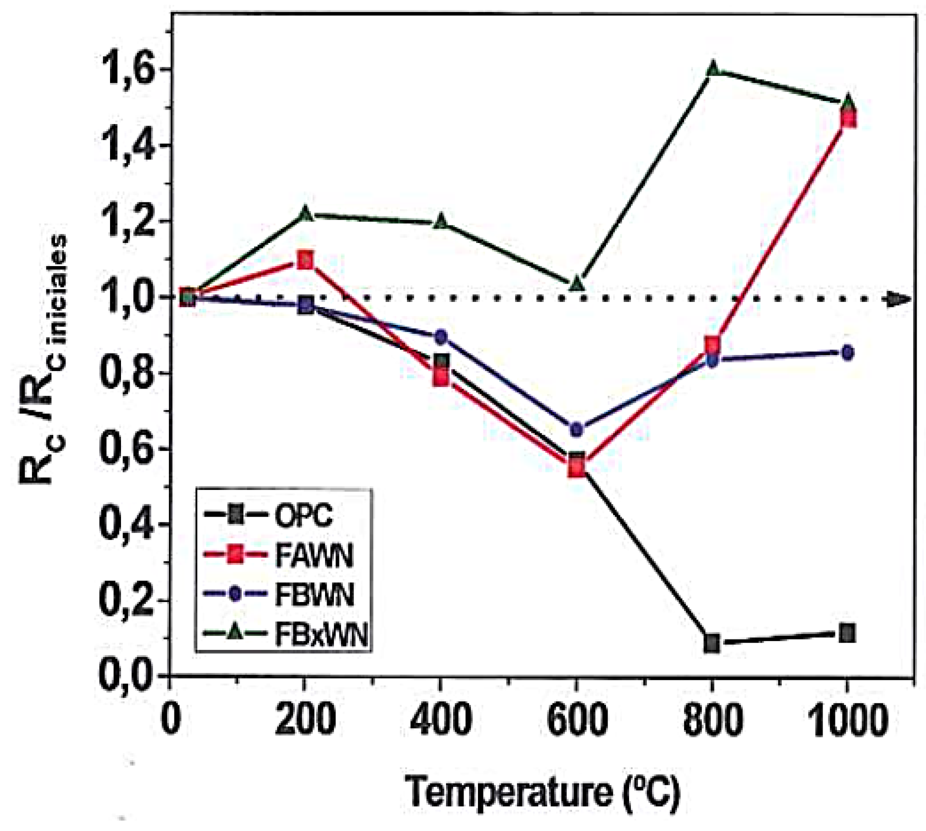


*Figure 3. Relative residual compressive strength ($\sigma_{FC}=\sigma_C/\sigma_{CO}$) versus temperature.* FBxWN is more efficient in resisting elevated temperatures, (especially at 1000 °C) than OPC, even after sudden thermal shock.

### - High temperature mechanical tests

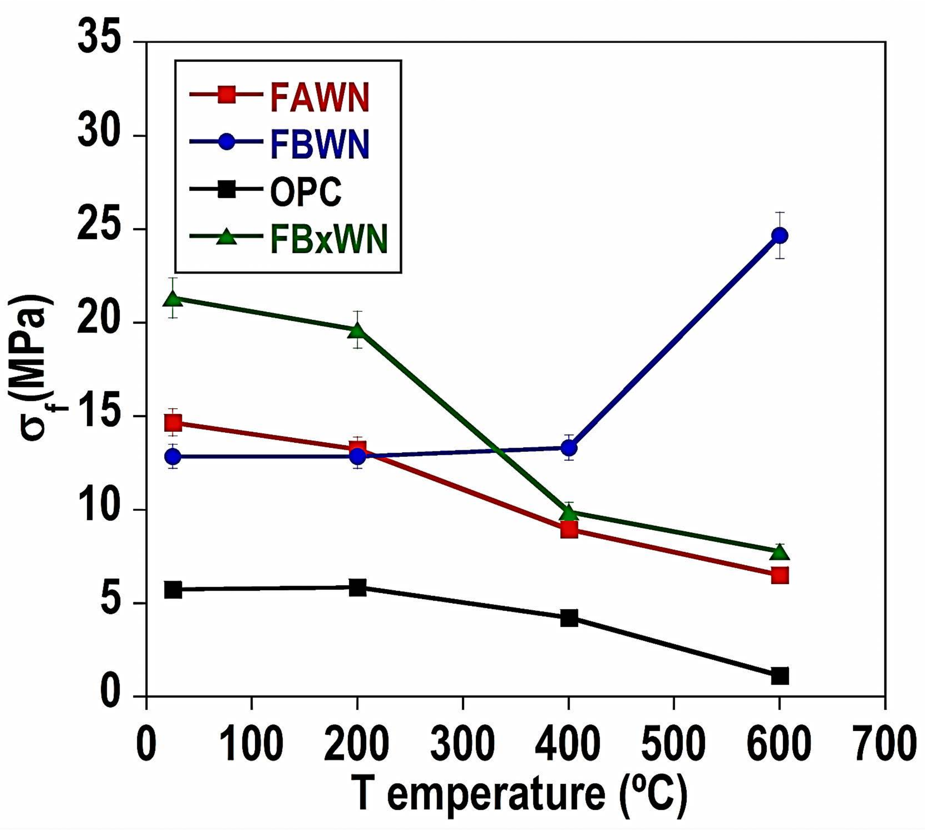


*Figure 4. Average flexural strength as a function of temperature.* Semi-plastic behavior was observed up to 600 ºC, all materials tested exhibited superior flexural strength than control pastes, FAWN and OPC.

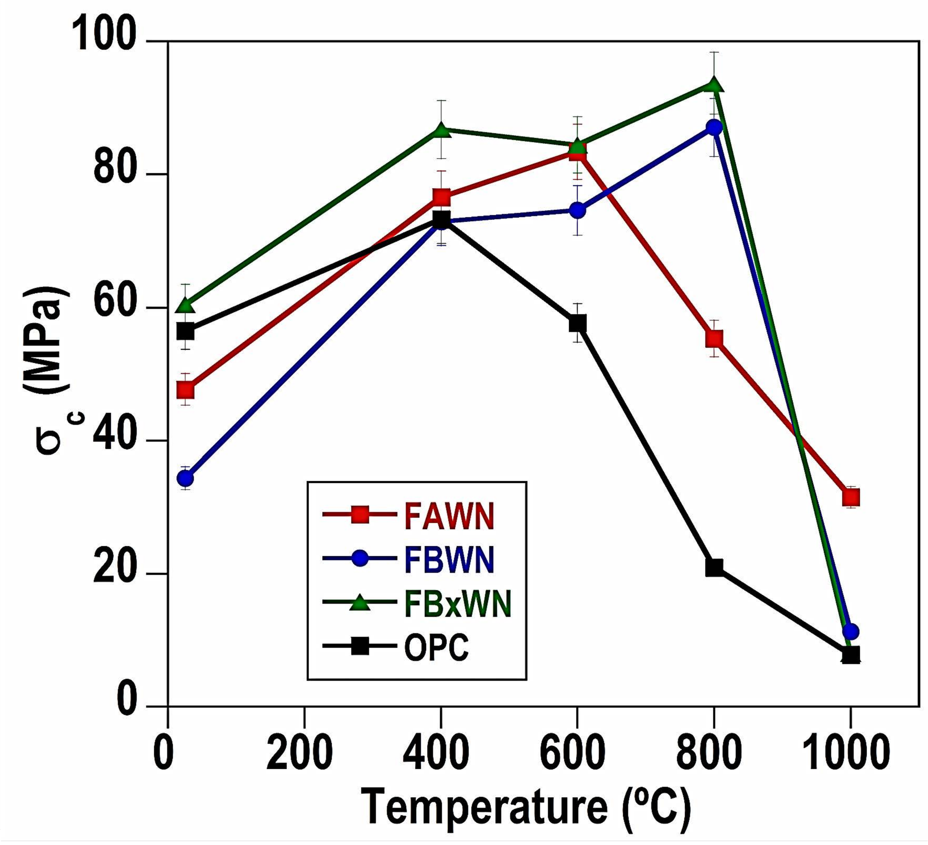


*Figure 5. Average compressive strength as a function of temperature.* Degradation of the material is inhibited by WN up to 400ºC, showing better mechanical properties than those of OPC.

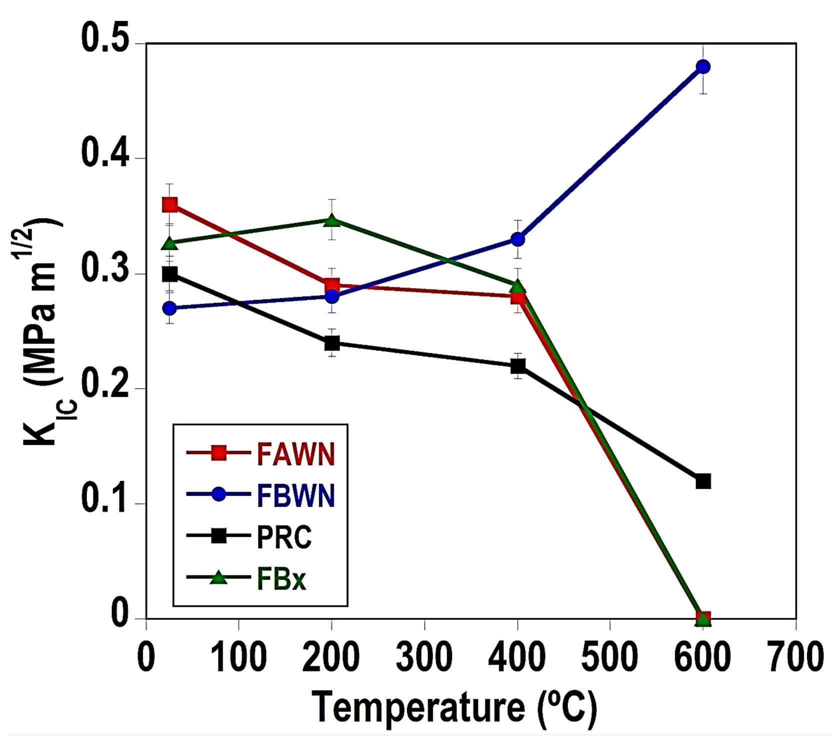


*Figure 6. Average fracture toughness versus temperature.*

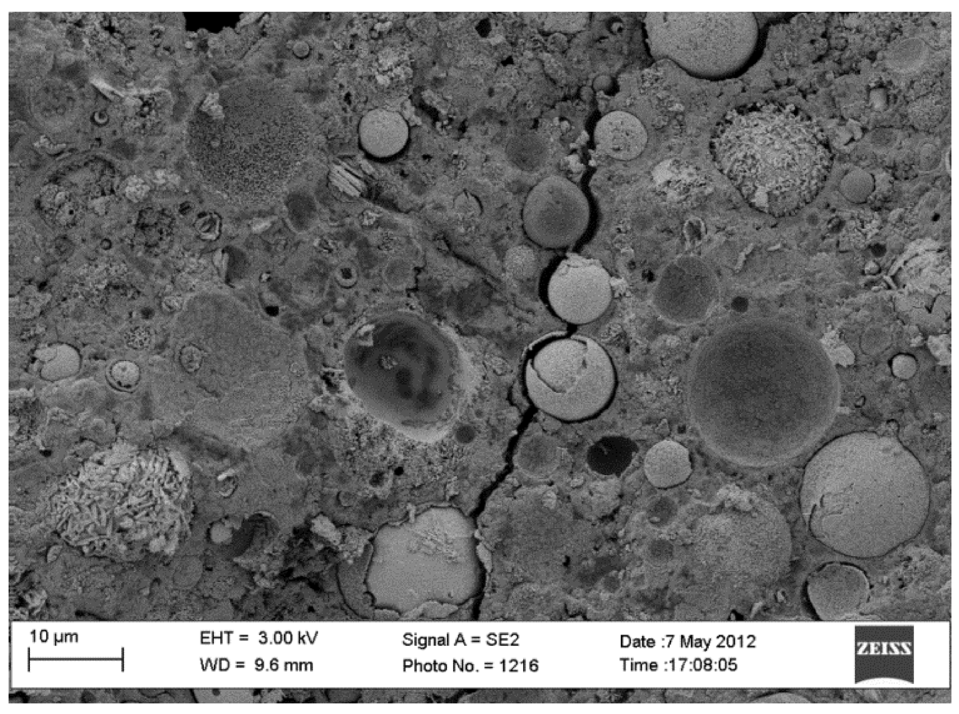

*Figure 7. SEM micrographs of fracture surface of FAWN sample tested at room temperature.*

The unreacted fly ash particles in the paste act as micro-aggregates which increase the resistance to crack propagation. Also, cracking around the fly ash particles results in more energy to be dissipated before failure.

**Acknowledgements**
This research project was funded by the Spanish Ministry of Science and Innovation under project BIA2010-17530. We would like to acknowledge many helpful discussions with our colleagues.